CE-MRA for Follow-up of Aneurysms Post Stent-Assisted Coiling

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Summary

This study compared the accuracy of contrast-enhanced MR angiography (CE-MRA) to intra-arterial cerebral angiography (IA-DSA) for assessment of intracranial aneurysms after stent-assisted coiling and to check if the presence of a stent in the parent artery diminishes the accuracy of CE-MRA.

Consecutive patients with cerebral aneurysms treated by stent-assisted coiling were evaluated retrospectively. Matching follow-up CE-MRA and IA-DSA were evaluated separately. Evaluation included the presence of aneurysmal remnant, patency and stenosis of parent artery.

Twenty-seven patients with 28 aneurysms and 33 matched CE-MRA and IA-DSA studies were evaluated. Nineteen aneurysmal remnants were seen on CE-MRA and 16 on IA-DSA. CE-MRA diagnosed three aneurysmal remnants not appreciated on IA-DSA. Five other remnants were larger on CE-MRA than IA-DSA. None of the remnants were missed on CE-MRA.

Parent arteries were patent on both modalities. CE-MRA showed false stenosis of the stented artery in six cases and exaggerated stenosis in two. In 18 cases, CE-MRA showed a short focal "pseudo-stenosis" where the stent's marker bands were located. This was noted whenever the stent's marker bands were located in an artery with luminal diameter ≤2 mm and was called "marker band effect".

CE-MRA is an accurate technique for follow-up of aneurysms post stent-assisted coiling with excellent depiction of remnants in spite of the presence of a stent. Apparent stenosis of the stented parent artery on CE-MRA is often false or exaggerated. "Marker band effect" should be recognized as an artifact that appears when stent's marker bands are in a small artery.

Introduction

Endovascular coiling has become the treatment of choice for most cerebral aneurysms since the results of the ISAT trial [1]. The major disadvantage of this technique is the possibility of aneurysm re-canalization due to coil compaction with a potential risk of future hemorrhage [2-6]. Follow-up of patients who have undergone endovascular treatment of aneurysms is therefore mandatory. MR angiography (MRA) has been shown to be as accurate as conventional cerebral angiography (DSA) for follow-up of aneurysms post coiling [7-11]. As the technique of endovascular coiling advances, it is applied to more complicated aneurysms such as aneurysms with a wide neck. This is often performed with device assistance such as balloon or stent-assisted techniques. After stent-assisted coiling, a stent is left within the parent artery at the neck of the aneurysm. This metal device can potentially influence the image quality of MRA and hinder its reliability in detecting aneurysmal remnants. The purpose of this study was to evaluate the accuracy of contrast enhanced MR angiography (CE-MRA) as compared to conventional intra-arterial cerebral angiography (IA-DSA) for the assessment of intracranial aneurysms after stent-assisted coiling. Specifically we tried to check if the presence of a stent in the parent artery at aneurysmal neck diminishes the accuracy of CE-MRA in diagnosis of aneurysmal remnants.

Materials and Methods

All consecutive patients with intra-cranial aneurysms that were treated by endovascular stent-assisted coiling in our institution between November 2003 and September 2008 were retrospectively evaluated. All patients had post coiling follow-up with both contrast enhanced MR angiography (CE-MRA) and intra-arterial catheter cerebral angiography (IA-DSA).

One interventional neuroradiologist (RA) reviewed the cases. The reviewer was presented with CE-MRA or IA-DSA images of the relevant vessels and was aware of the location of the treated aneurysm in each case. The reviewer was presented with AP, LAT and spin views of the relevant vessel on IA-DSA and with axial source images and previously produced 3D MIP reconstructions of the CE-MRA.

The studies were evaluated separately; review of CE-MRA of all patients was followed by a review of the IA-DSA of all patients separated by one week and not at the same order. The reviewer evaluated each study for the presence of residual/recurrent aneurysm, patency of the parent vessel and stenosis of parent vessel. As a second stage, after this separate review took place, the reviewer performed another evaluation. In this evaluation, the reviewer compared paired CE-MRA and IA-DSA for each patient. In this evaluation of paired studies, the reviewer compared the apparent size of residual aneurysm and the degree of parent vessel stenosis – when relevant.

Magnetic Resonance Angiography (CE-MRA)

MRA examinations were performed using a 1.5 Tesla MR scanner (GE Medical Systems, Milwaukee, Wis., USA) with a standard eight channel head coil. The MRA examinations all included a CE-MRA using Gadovist (Bayer, Germany) injected at a rate of 1.5 cc per second to a total of 15 cc followed immediately by a flush of 30 cc of saline. The specific method in use at our institution is an auto-triggered elliptic centric ordered 3D Gadolinium-enhanced MR angiography [9]. This method of CE-MRA results in essentially the same images to more ubiquitous forms of commercialized monitored or "fluoro-triggered" CE-MRA used in many centers worldwide. The source images consist of an elliptic centric ordered 3D fast SPGR sequence oriented in the axial plane, with coverage from the foramen magnum to above the circle of Willis, with the following parameters: 3.7/1/1.1 (repetition time ms/echo time ms/tip angle); fractional echo acquisition; field of view, 22·22 cm; matrix, 320·320; bandwidth, 62.5 kHz; section thickness, 1.0 mm; flip angle, 30; 76 sections resulting in a 7.6 cm-thick volume; and a scan time of 2 min. Resultant voxel dimensions were 0.7·0.5·1.0 mm (this resolution was obtained without zero filling techniques). 3D MIP reconstructions were available as well.

Catheter Cerebral Angiography (IA-DSA)

Catheter-based intra-arterial cerebral angiography (IA-DSA) was performed in all patients using a dedicated biplane neuroangiography suite (General Electric, LCN+, Buc, France). All IA-DSA examinations included frontal and lateral views with selective injection of the appropriate internal carotid or vertebral arteries. All IA-DSA examinations also included a subtracted rotational (spin) angiogram acquisition with selective arterial injection. The amounts of iodinated contrast medium (Omnipaque 300, GE Healthcare, Chalfont St. Giles, UK) injected for the AP and lateral view were; 5 cc per second to a total volume of 10 cc for the carotids and 3-4 cc per second to a total of 7-8 cc for the vertebral arteries. For the rotational views 4 cc per sec to a total of 20cc were used for the internal carotid and 3 cc to a total of 15 cc for the vertebral artery.

Results

Twenty-seven patients with 28 aneurysms following stent-assisted coiling were retrospectively evaluated. This includes 20 women and seven men between 38 and 70 years of age (average 51.6 years). One patient had two aneurysms coiled with stent assistance.

All aneurysms were followed after coiling with CE-MRA and IA-DSA. The 28 aneurysms received 33 paired CE-MRA and IA-DSA studies. Three of the coiled aneurysms had two pairs of matched CE-MRA and IA-DSA (on separate occasions) and one patient had three matched follow-up studies (on separate occasions). The time frame between the paired CE-MRA and IA-DSA studies ranged between same day and 214 days (average 89 days, median 69 days). Sixteen of the matched studies (52%) are within 60 days of each other (average 20 days, median 14 days) and 17 studies are separated by more than 60 days (average 154 days, median 176 days). In 25 cases the IA-DSA was performed prior to the CE-MRA, in eight cases the CE-MRA was performed prior to IA-DSA and in one case both were performed on the same day.

The locations of the aneurysms evaluated appear in Table 1. They include: eight basilar tip, two basilar artery side wall, one vertebro-basilar junction, one distal vertebral, three posterior communicating artery (Pcom), two anterior communicating artery (Acom), three carotid termination, six paraophthalmic carotid and two cavernous carotid. The sizes of the coiled aneurysms (according to largest diameter) ranged from 2.5 mm to 16 mm (average 9 mm).

Fifteen of the aneurysms were asymptomatic, one presented with sixth cranial nerve palsy and 12 were originally ruptured aneurysms. The indication to use a stent in asymptomatic unruptured aneurysms was a wide aneurysmal neck (prior or after recurrence) and failed balloon assistant coiling. In ten of the ruptured patients the stent was deployed during retreatment for aneurysmal residual or recurrence, remote from the SAH. In two patients with acutely ruptured aneurysm the stent-assisted procedure was performed as a primary approach at the time of acute SAH. In one of these ruptured patients the stent was placed at the time of acute SAH after failure of attempted balloon assisted coiling. In one patient the stent was deployed as a rescue procedure due to coil extrusion into the parent vessel. In this case the aneurysmal neck was wide as well.

The types of stents used were: 15 Neuroform stents, five Neuroform-2, one Neuroform-3 (Boston Scientific), five Enterprise (Cordis) and two Leo (Balt) stents. All are self-expandable nitinol stents. The Leo and the Enterprise stents are closed cell design and the Neuroform is hybrid cell design. The sizes of stents used were: Neuroform: one 2.5×25 mm, two 3×20 mm, four 3.5×20 mm, one 4×15 mm, three 4×20 mm, one 4.5×15 mm, three 4.5×20 mm. Neuroform-2: two 3×20 mm, one 3.5×20 mm, one 4.5×20 mm and one 4.5×30 mm. Neuroform-3: one 2.5×20 mm. Enterprise: three 4.5×22 mm and two 4.5×37 mm. Both Leo stents were 4.5×25 mm.

Results of Reviewer's Evaluation

Aneurysmal remnants

Of the 33 matched studies, 19 aneurysmal remnants were seen on CE-MRA and 16 were seen on the IA-DSA studies. Three remnants seen on CE-MRA were not detected on IA-DSA (Figure 1). Out of the 16 remnants that were detected on both modalities, 11 were equal in size on both modalities (Figure 2) but five were significantly larger on CE-MRA than on IA-DSA (Figure 3). In total there was disagreement between CE-MRA and IA-DSA in eight cases (either no remnant on IA-DSA or larger remnant on CE-MRA). In five of these cases MRA was performed a significant time later than IA-DSA (69 to 188 days later, average: 151 days, median: 164 days) and thus the remnant might have developed in the interim. In three of these cases, MRA was performed earlier than IA-DSA (one day and 43 days) or in great proximity but after IA-DSA (two days). In these three cases it is likely that CE-MRA had a better depiction of the remnant. Two of those three cases were larger remnant on CE-MRA (MRA two days after and 43 days prior to DSA) and in one case the remnant was not seen on IA-DSA (MRA one day prior to DSA). These three cases all demonstrated the "helmet effect" [10] explaining the superior depiction of the aneurys-

Table 1 **Location of aneurysms included in this study after stent-assisted coiling.**

Posterior circulation		**Anterior circulation**	
Basilar tip	8	Carotid termination	3
Basilar side wall	2	Acom	2
Vertebro-basilar Junction	1	Paraophthalmic	6
Distal vertebral	1	Cavernous carotid	2
Pcom	3		
Total	15	Total	13

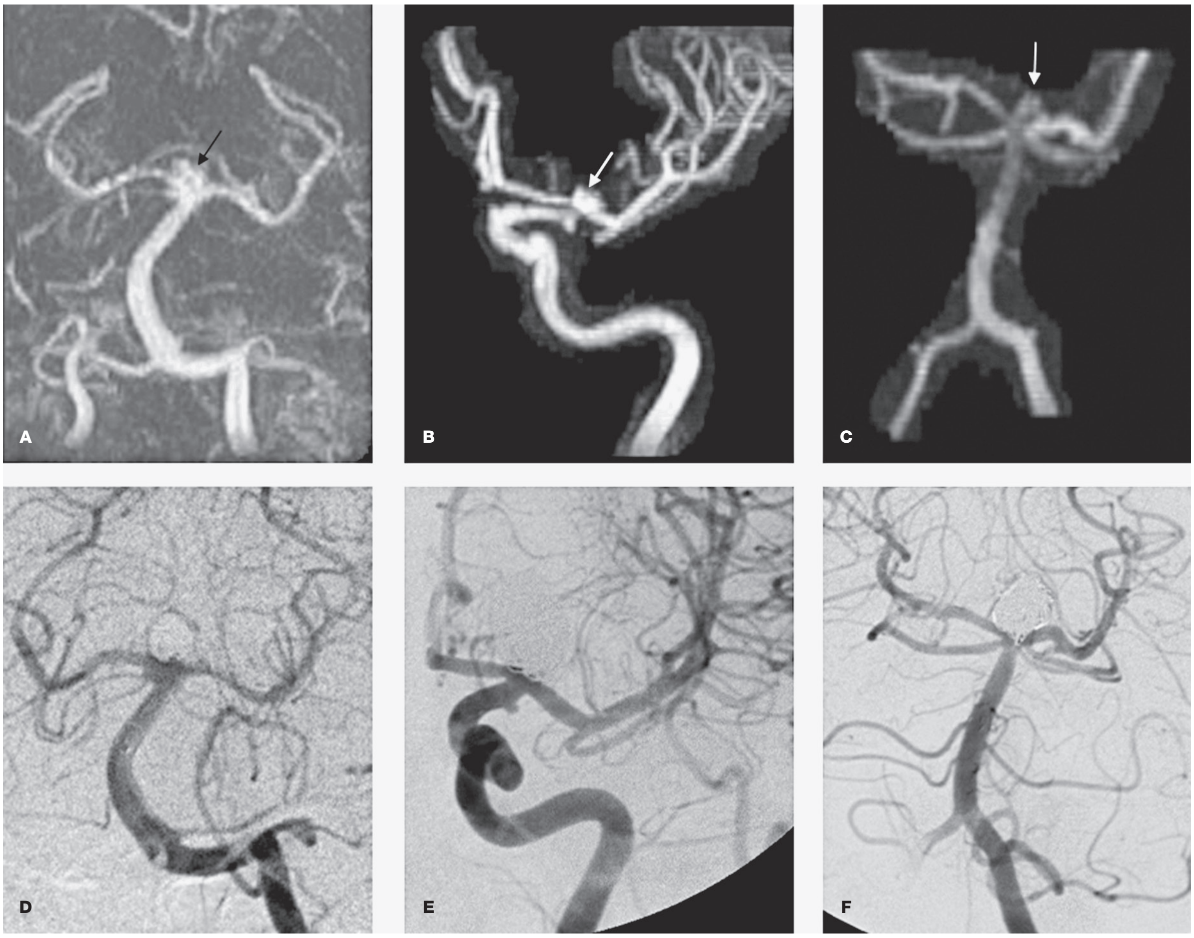

Figure 1 Aneurymal remnants in 3 patients that were not demonstrated on IA-DSA but seen on CE-MRA. Paired CE-MRA and IA-DSA images are presented (A and D, B and E, C and F). All are cases in which an aneurysmal remnant is shown on CE-MRA (arrow in A, B and C) but not depicted on IA-DSA (D, E and F). Patient A underwent both examinations 1 day apart. Patients B and C had the CE-MRA 6 and 5 months after IA-DSA and thus could potentially represent recurrence of aneurysm that was not present at the time of IA-DSA.

mal remnant on MRA. There were no aneurysmal remnants missed by CE-MRA and none appeared smaller on CE-MRA.

Changes in parent artery

All parent arteries were noted to be patent on both CE-MRA and IA-DSA. Of the 33 matched studies, stenosis of the parent artery, at the stented region, was demonstrated on both IA-DSA and CE-MRA in ten cases. CE-MRA showed stenosis in eight more cases that were not evident on IA-DSA (Figure 2). Of the ten cases that showed stenosis on both CE-MRA and IA-DSA, the stenosis was of the same degree in six cases and worse on CE-MRA in four. In total, the appearance of the parent artery on CE-MRA did not match that of IA-DSA in 12 cases. In four of these 12 cases IA-DSA was performed a significant time prior to CE-MRA. In eight of these cases IA-DSA was performed on the same day as CE-MRA (one case), after CE-MRA (five cases) or in great proximity prior to CE-MRA (two cases, (two days and 19 days apart)). In these eight cases it is therefore reasonable to conclude that IA-DSA does indeed represent the "gold standard" with regard to stenosis and that CE-MRA does not depict the true status of the artery. In these eight cases, CE-MRA showed false stenosis of the stented parent artery in six cases and exaggerated stenosis in two. The stents present in these eight cases include: four *Neuroform* (in five matching studies), one *Neuroform*-3 and two Enterprise stents. The six

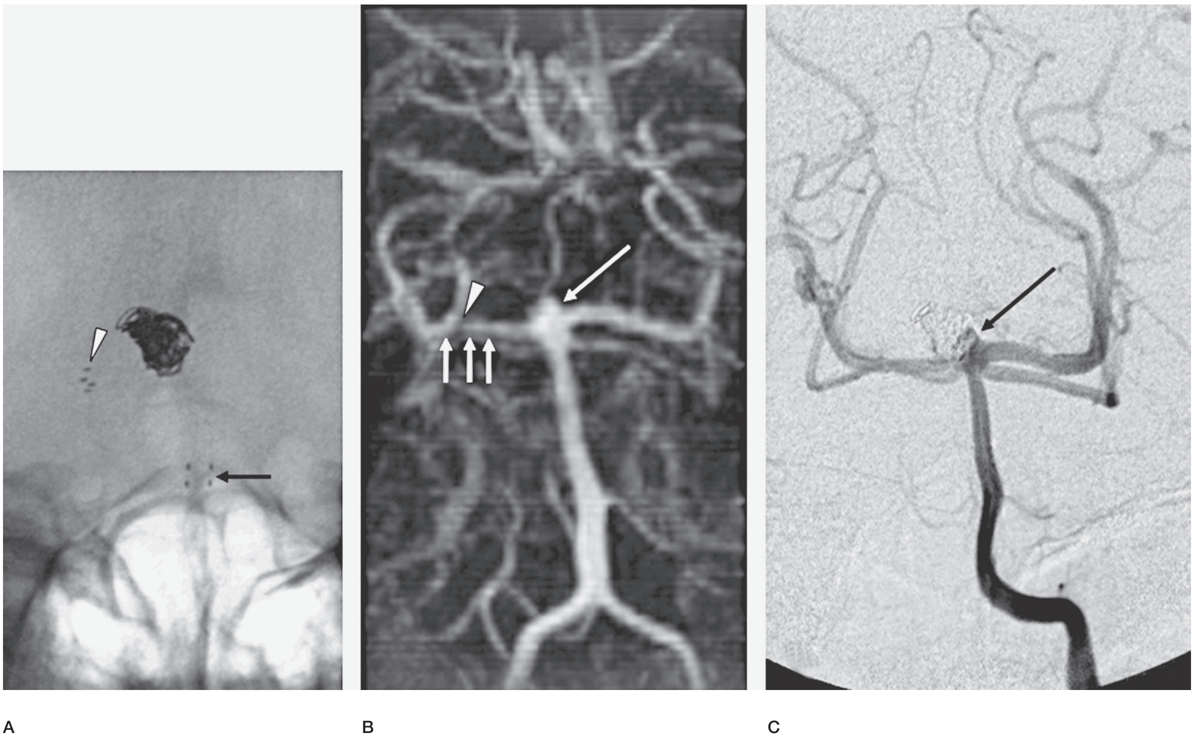

Figure 2 False stenosis of parent artery and "marker band effect" on CE-MRA. A) Plain film in AP projection post stent-assisted coiling of a basilar tip aneurysm shows the proximal marker bands of the Neuroform stent (arrow) located in the mid-basilar artery and the distal marker bands (arrow head) located in the P1-P2 junction of the PCA. B) AP MIP reconstruction of CE-MRA demonstrates a small aneurysmal remnant (long arrow) as well as the "marker band effect" at the distal marker bands (arrow head) but not at the proximal marker bands. The right P1 segment of PCA seems to be narrowed (short arrows). C) AP projection of left vertebral artery injection from IA-DSA does not show narrowing of the right P1 segment nor does it show the marker band effect. The aneurysmal remnant is similar in size on both modalities (long arrow in B and C).

cases with parent artery stenosis that matched between CE-MRA and IA-DSA were: two Neuroform (in three matching studies), one Neuroform-2, one Leo and one Enterprise.

In addition to the above stenoses along the length of the stented portion of the artery, the reader recognized 18 cases with focal short "tight stenosis" noted only on CE-MRA (Figures 2, 4 and 5). These "stenoses" were always located at the presumed location of the ends of the stent where the stent's marker bands are located. Since none of these "stenoses" were seen on IA-DSA we have subsequently termed this the "marker band effect" of CE-MRA. The marker band effect was noted in 16 cases at the distal end of the stent (Figures 2 and 4) and in two cases in both proximal and distal ends of the stent (Figure 5). Eleven of these focal stenoses were seen at the P1 segment of the posterior cerebral artery (PCA), four at the M1 segment of the middle cerebral artery (MCA), two at the A1 segment of the anterior cerebral artery (ACA), and two at the A2 segment of ACA. The cases in which this effect was not seen were all cases in which the entire length of the stent was deployed in larger arteries (Figure 3) such as internal carotid artery (ICA), basilar artery or vertebral artery. This focal stenosis was only noted in arteries 2 mm or smaller where the marker bands come close to each other (A1, A2, M1, M2, P1, P2) and was never seen when the marker bands lie within a larger artery (such as, internal carotid artery, vertebral artery or basilar arteries). The marker band effect was seen

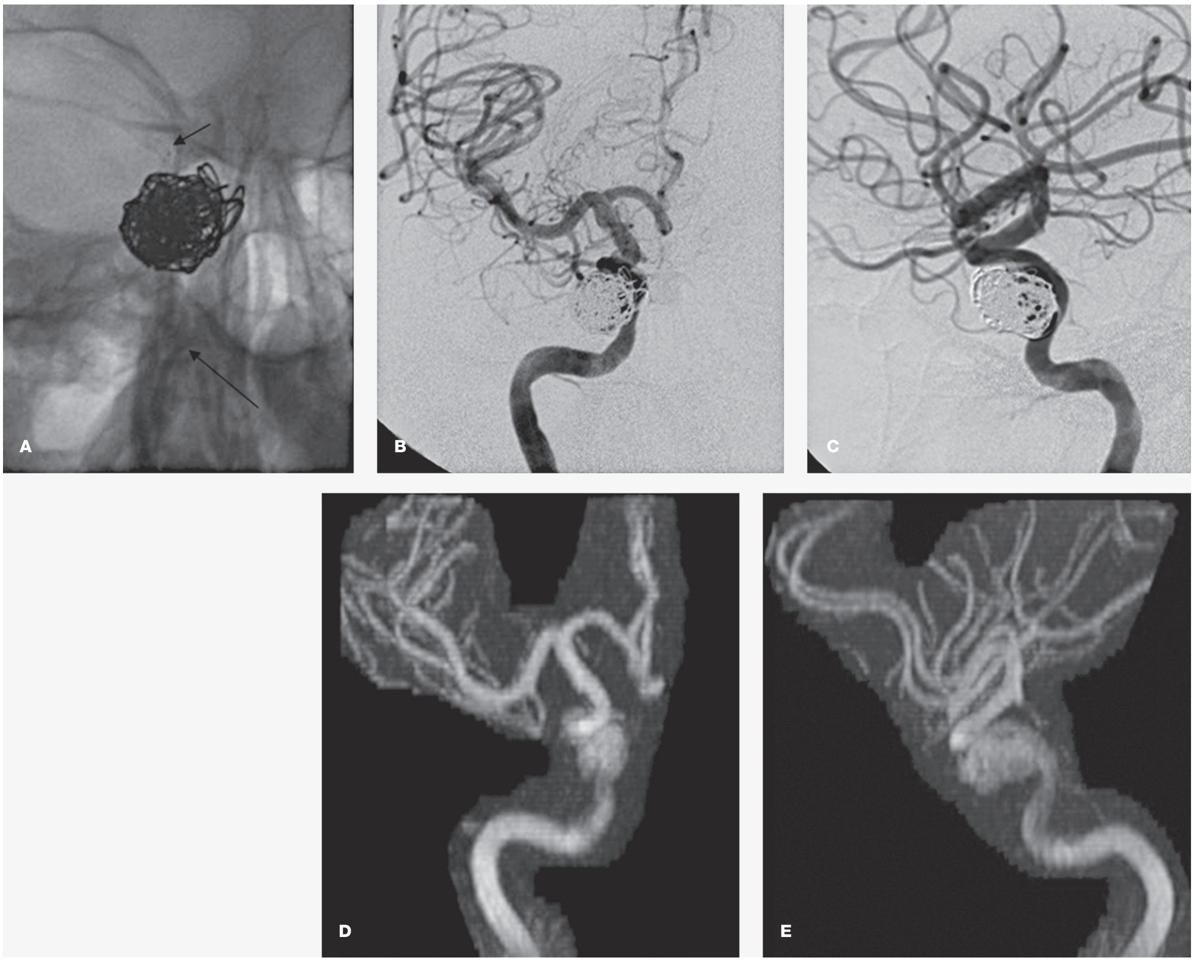

Figure 3 Aneurysmal remnant larger on CE-MRA than on IA-DSA. A) A giant cavernous carotid aneurysm post stent-assisted coiling with an Enterprise stent. AP plain film shows the coil mass and the stent marker bands (proximal marker bands – long arrow, distal marker bands – short arrow). IA-DSA (B and C) of the right carotid artery and matching MIP views of CE-MRA (D and E) performed 2 days apart demonstrate a large aneurysmal remnant. The remnant is depicted on both modalities however its full extent is not appreciated on the IA-DSA as it is on the CE-MRA. Parent artery stenosis is noted similarly on both modalities. There is no "marker band effect" since the proximal and distal marker bands of stent are within the internal carotid artery which is a relatively large vessel.

in the following stents: ten Neuroform (14 matching studies) one Neuroform-2 and one Neuroform-3 and two Enterprise stents. Leo stent was not deployed in an artery measuring 2 mm or smaller in this study group.

Discussion

The re-canalization rate of coiled aneurysms is reported to be as high as 34% [2-6] with a risk of re-bleeding of up to 2.6%. Since re-bleeding is regarded as a result of re-canalization, these patients require frequent follow-up imaging for several years after coiling. Follow-up of aneurysms treated with endovascular coiling was originally performed with conventional cerebral angiography (IA-DSA).

However, IA-DSA is an invasive technique that carries a risk of stroke and other complications [12]. MR angiography (CE-MRA) has emerged as the non-invasive alternative to IA-DSA for the follow-up of coiled aneurysms and has replaced IA-DSA for this purpose in many institutions.

Several studies compared MRA to IA-DSA and have shown that MRA is an accurate technique to reveal aneurysmal remnants and re-canalization after endovascular coiling [7,9,10,13-15]. Some studies evaluated contrast-enhanced

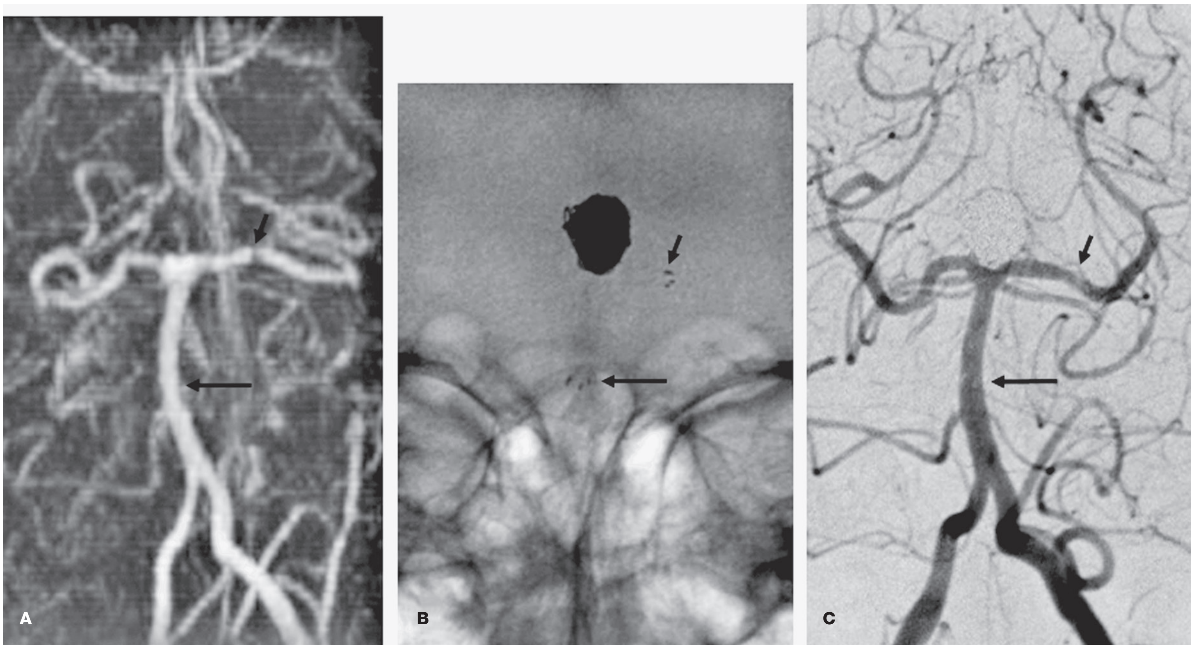

Figure 4 "Marker band effect" in a patient after stent-assisted coiling of a basilar tip aneurysm. AP MIP reconstruction of CE-MRA (A) and the matching AP image of IA-DSA (C) of the posterior circulation. B) A non-subtracted IA-DSA image showing the coil mass and the proximal (long arrow) and distal (short arrow) marker bands of a Neuroform-2 stent for reference. CE-MRA (A) demonstrates a focal stenosis, "marker band effect", at the distal marker bands (short arrow) with no such effect at the proximal marker bands (long arrow). This is since the distal marker bands are located in P1 which is a small artery while the proximal marker bands are located in the basilar artery which is larger than 2 mm in diameter. IA-DSA (C) does not demonstrate an apparent narrowing or marker band effect, although the location of the distal marker bands is evident (short arrow).

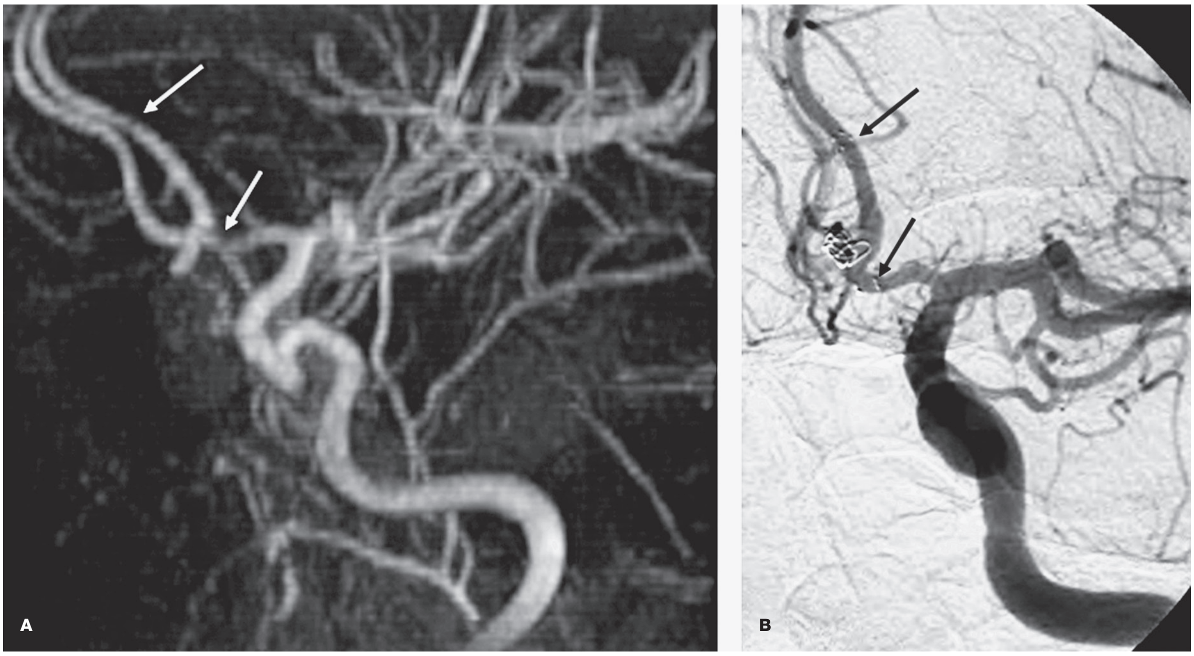

Figure 5 Proximal and distal "marker band effect" in a case of stent-assisted coiling of Acom aneurysm. Matching oblique views of CE-MRA (A) and IA-DSA (B) of the left ICA show the proximal marker bands of a Neuroform-2 stent in the A1 segment of the ACA and distal marker bands in the A2 segment (arrows in B). The CE-MRA demonstrated the "marker band effect" in both these locations since A1 and A2 are either 2mm or smaller diameter. (Note: this specific IA-DSA image is from a run prior to complete occlusion of the aneurysm with coils).

techniques [8,10,14,15] while others evaluated MRA techniques with no contrast administration such as 3D TOF [7,9,13] or both [16,17]. A few studies have suggested that MRA is superior to IA-DSA in demonstrating some aneurysmal remnants [10,13]. This is especially evident for remnants that extend or invaginate into the coil mass. In these cases, the coils that surround the aneurysmal remnant create an impenetrable radio dense "helmet" around the remnant such that it is difficult to appreciate the remnant on IA-DSA (despite complete AP, LAT and rotational views) due to lack of photon penetration through the coil mass.

Adding multiple angled oblique projections in addition to the standard AP, lateral and rotational views might or might not help to visualize such a remnant on IA-DSA assuming one was aware of its existence. MRA enjoys a distinct advantage over DSA for the visualization of this type of remnant since it does not suffer from the helmet phenomenon and there is only minimal susceptibility artifact arising from platinum coils [18].

In the current study we support previous publications and show again that CE-MRA is an accurate technique to reveal aneurysmal remnants and recurrences. Furthermore we were able to show that the presence of a metal stent in the parent artery at the aneurysmal neck does not impair the ability of CE-MRA to reveal remnants.

In this study, CE-MRA revealed all of the remnants depicted by IA-DSA as well as three more. One of these is a definite false negative of IA-DSA since CE-MRA was performed one day earlier. In addition, five of the remnants depicted by both CE-MRA and IA-DSA were larger on CE-MRA. In two of these cases CE-MRA was performed earlier than IA-DSA and thus CE-MRA likely represents the reality rather than an aneurysm that grew in the interim between studies.

CE-MRA did not suggest false occlusion of any of the parent arteries. It did however demonstrate false narrowing of several parent arteries at the stented portion. In this study CE-MRA showed false stenosis of the stented parent artery in six cases and exaggerated stenosis in two. Metal stents were shown to cause artifactual stenosis on CE-MRA with carotid stents [19]. It was shown to result from flow, susceptibility and radio-frequency artifacts. Susceptibility artifacts result from local in-homogeneities of the magnetic field due to the metallic stent struts. Cage-like implants such as stents were show to cause radio-frequency caging [19-21]. While the susceptibility is not enough to impair depiction of aneurysmal remnants, it will sometimes, reduce the appearance of the patent lumen especially in stents with smaller diameter [19].

This study suggests that an apparent arterial stenosis within a stent on CE-MRA is not a reliable finding and could either be false or exaggerated. An interesting phenomenon demonstrated in our group of patients was the "marker band effect". This effect is the appearance of a short focal stenosis of the parent artery on CE-MRA at the location of the proximal or distal marker bands of the stent. This was seen in 18 of our 33 cases.

Most of these showed this effect at the distal marker bands and two at both proximal and distal marker bands. This effect appeared in all the cases that had the proximal and/or distal marker bands located in a small artery (2 mm in diameter or less). This artifact is most likely due to the marker bands being thicker and of different alloy than the rest of the stent (usually made of platinum) which creates a stronger local susceptibility artifact. Since susceptibility artifact is greater in smaller vessels [19], it commonly occurred at the distal end of the stent since most of the stents extend in a way that their proximal marker bands are in a relatively large artery and their distal marker bands are in a small artery (ICA to M1 or Vertebral artery to P1, etc.).

In two of our cases the stent extended from A1 to A2 segment of the ACA. These two cases showed the marker band effect both at the proximal and distal ends of the stent. This effect was not noted on IA-DSA and should not be regarded as real stenosis but rather as an artifact produced by closely opposed metal marker bands within a small vessel lumen. This is a retrospective observational study and its main limitation is that the images were reviewed by only one observer, thus inter-observer agreement rates cannot be provided.

The other main limitation of this study is obviously significant time spacing, in some of the cases, between CE-MRA and IA-DSA. This might introduce an obvious error since aneurysms may recanalize and recur with time. In about half of our cases, CE-MRA and ID-DSA were performed within 60 days of each other (average 20 days, median 14 days) however, the other half were separated by more than 60 days (average 154 days, median 176 days). This time gap might explain five of eight cases with discrepancies in aneurysmal remnant depiction between IA-DSA and CE-MRA. In three of these eight cases the superiority of CE-MRA in remnant depiction is clear.

Furthermore, the fact that no aneurysmal remnants were missed by CE-MRA and none appeared smaller on CE-MRA supports CE-MRA is a reliable technique even in face of this time gap. Lastly, we reviewed 28 aneurysms with a small sample size of each type of intracranial stent.

Conclusions

CE-MRA is an accurate technique for follow-up of aneurysms post stent-assisted coiling. The presence of a stent in the parent artery at aneurysmal neck does not diminish the accuracy of CE-MRA in diagnosis of aneurysmal remnants. The presence of apparent stenosis at the stented parent artery on CE-MRA is often false or exaggerated. “Marker band effect” should be anticipated and recognized as an artifact that appears when the stent’s marker bands are located in a small artery.

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